BGS Performance for Low Energy Recoils with Nitrogen as the Fill Gas

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In recent experiments we have tested the Berkeley Gas-filled Separator (BGS) performance for low energy heavy reaction products with nitrogen replacing helium as the fill gas.

Our motivation is to learn if nitrogen can lead to a similar or even an enhanced efficiency for delivering such recoils to the focal plane in spite of the increase in scattering that results from the use of a higher Z gas. A higher collection efficiency could result from a more narrowly defined distribution in magnetic rigidity (arising from recoil interactions with the less tightly bound electrons of the nitrogen molecules).

An advantage of replacing helium with nitrogen is that nitrogen makes it easier to implement differential pumping to isolate the dilute gas atmosphere of the BGS from the high vacuum environment of the cyclotron. Such a system would eliminate the need for a thin carbon window at the entrance to the BGS. Eliminating the window would allow the use of higher beam currents to obtain higher production yields and would allow the use of heavier beams.

To track the performance of the BGS with the two gases we made use of ^{214}Ac recoils produced in the 5*n* channel from the reaction of a ^{22}Ne beam on a 0.39 mg/cm^2 target of ^{197}Au. The test with helium was done using a beam energy of 112.2 MeV leading to a recoil velocity of about 1.3 v/v_0 while the test with nitrogen employed a beam energy of 118.8 MeV leading to a beam energy of about 1.4 v/v_0. (Here the velocity is expressed in units of the Bohr velocity v_0 = 2.19 x 10^6 m/s.) We identified the presence of the ^{214}Ac recoils implanted into the focal plane detector through their decays by α-emission.

For the test with helium we set the pressure within the BGS to 200 mTorr. We measured the horizontal distribution of ^{214}Ac by examining the variation in α-activity among the vertical strips of the detector. We measured the vertical distribution by observing the activity as we varied the vertical position of the focal plane detector.

For the test with nitrogen, we measured the horizontal and vertical distributions of ^{214}Ac recoils for a number of pressure settings, finding an optimum setting of about 50 mTorr.

The vertical distribution of recoils obtained with nitrogen was significantly larger than that obtained with helium – 11 cm FWHM compared to 7 cm. Since the BGS does not provide vertical dispersion, the increased distribution results from an increase in multiple scattering of the recoils from the gas molecules.

The horizontal distribution of recoils was slightly smaller in the case of nitrogen than for helium – 15 cm compared to 16 cm. This result shows that the nitrogen results in a narrower magnetic rigidity distribution. The broadening in the horizontal distribution from multiple scattering is offset by the better-defined rigidity.

It is clear that for the reaction we have considered, the use of nitrogen leads to a loss in the overall BGS transport efficiency from scattering, even though this gas leads to a more narrow distribution in rigidity. This test, however, suggests that there still may be cases – with heavier or higher energy recoils that are less susceptible to scattering – where it makes sense to replace helium with nitrogen as a fill gas.

Footnotes and References

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